Soil organisms

Kinds, roles and inter-relationships

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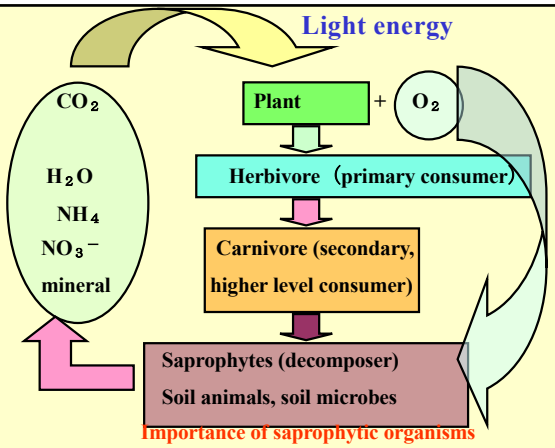
http://timetraveler.html.xdomain.jp



Importance of saprophytic organisms

Organisms in surface soil

- Plant roots
- Mammals
- Soil animals
- Soil microbes

Biomass of soil organisms /1 ha reaches several tons:
5 t / ha, 0.5kg / m^2

Biomass of soil organisms (some t / ha) is almost equivalent to the yield of crops harvested annually from the land, or to the weight of domestic animals bred on the land.

Yield of rice: ca. 5 t /ha = 500 kg /10 a

Breeding density of cows:

1–2 heads / ha = 1.5 t / ha

Role of soil to the crowd of soil organisms:

Moisture, Oxygen, Temperature, Mineral nutrition, Supply of organic matter

What soil owes to the crowd of soil organisms:

Decomposition of organic matter, emission of carbon dioxide, liberation of mineral nutrients

Creation of soil structure

Supply of fertile plant growth environment

Soil animals (soil fauna)

Macrofauna

Animals sized >2mm or 10mm

Earthworms, Enchytraeina, ants, Millipede, Centipede, etc.
Population of earthworms :

3000-250,000 /10a, 3-250 /m^2

Function of earthworms

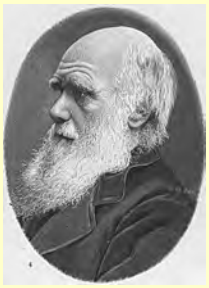
Amount of soil passing through the body of earthworm :

4t / 10a annually

In 30-50 years, all the soil in the plowed layer passes through the body of earthworms.

200 t / 4 t = 50 years

Charles Darwin



"The Formation of Vegetable Mould through the Action of Worms, with the Observation of their Habits" (1881)

Japanese translations:

S. Yata (1949), H. Watanabe (1994) (平凡社)

Clods of the feces of earthworms
(Baybay, Leyte, Philippines)

Functions of soil animals: Eating and crushing plant remains and animal feces

- **Decomposability of plant remains increases after eaten and crushed by soil animals.**
- **Animal feces are first eaten and decomposed by the larva of insects (eg. Dung beetles and flies).**

Organic matter decomposition by soil animals

Temperate region: Arthropods and earthworms

Tropics and subtropics: Termites

Sub-boreal needle forest: Enchytraeina

Mesofauna

Size: 0.2-2 mm ～ 10 mm

Collembola (spring tails), mites, nematodes

Population:

Collembola and mites: 50,000-80,000 /m^2 in forest floors.

Nematoda: (saprophytic, predatory, parasitic)

1.30 million /m^2 in the forest,

50,000-80,000 /m^2 in cultivated lands.

Microfauna

Size: < 0.2mm

Protozoa:

Amoeba, Ciliates, Flagellate

Collembola (アカトビムシ)

Collembola (マルトビムシ)

Oribatid (ササラダニ)

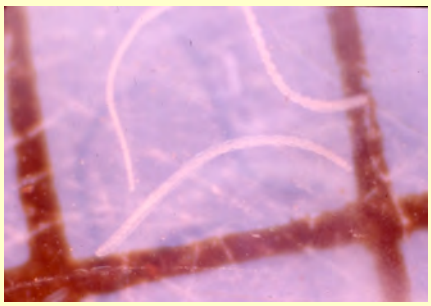
Prostigmata (ケダニ)

Isopoda, sow bug (ワラジムシ)

Lithobius (イシムカデ)

Larva of millipede
（ヤスデ綱幼虫）

Larva of Diptera (flies)
双翅目（ハエ目）幼虫



Enchytraeina (ヒメミミズ)

Pratylenchus penetrance
(キタネグサレセンチュウ)

Nematodes isolated from OUAVM fields.

Lumbricus rubellus
（ツリミミズ）

Length: 6-10 cm
Living depth: 10-25 cm

Collected from compost

Amynthus agrestis
（フトミミズ）

Length: 8-20 cm
Living depth: 10-50 cm

Collected from compost

Population of soil animals / m^2 (Kitazawa, 1976)

kinds	Needle forest	Mulberry field	Upland field
Macrofauna	73	16	19
Enchytraeina ($\times 10^3$)	150	6.5	3.7
Collembola ($\times 10^3$)	76	5.0	9.3
Mites ($\times 10^3$)	53	8.1	5.8
Nematodes ($\times 10^5$)	13	7.0	1.4

Soil microbes

Bacteria, Actinomycetes,

Fungi, Algae

Classification of organism by the method to obtain carbon.

From organic matter....

organotrophs, heterotrophs

From carbon dioxide .....

lithotrophs, autotrophs

Classification of organism by the method to obtain energy.

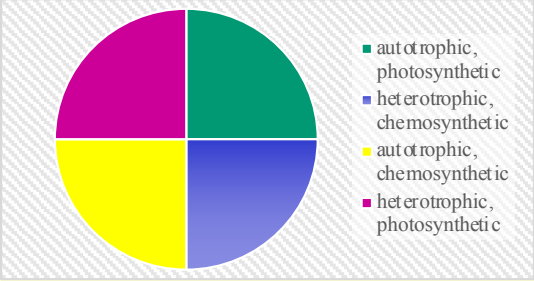
From the light .....

Photosynthetic organisms

From the chemical compounds, such as methane, hydrogen sulfide, hydrogen gas, etc. ...

Chemosynthetic organisms

Classification of organisms according to the types of metabolism



Classification of organisms according to the types of metabolism

Types of metabolism	Members of the group
Autotrophic, Photosynthetic	Higher plants, algae, Chromatiales bacteria, Chlorobiales bacteria
Heterotrophic, Chemosynthetic	Animals, fungi, actinomycetes, most of bacteria
Autotrophic, Chemosynthetic	Ammonium oxidizing bacteria (Nitrosomonas), Nitrite oxidizing bacteria (Nitrobacter), Iron bacteria, Hydrogen bacteria, Sulfur oxidizing bacteria (Thiobacteria)
Heterotrophic, Photosynthetic	Purple bacteria (Rhodobacteria, Blastochloris)

Function of soil microbes

- **Mineralization of organic matter**
- **Secretion of soil enzymes**
- **Decomposition and purification of harmful organic matter**
- **Symbiotic relationship with plants**
- **Antagonism (competition) with disease causing germs**

Mineralization of organic matter

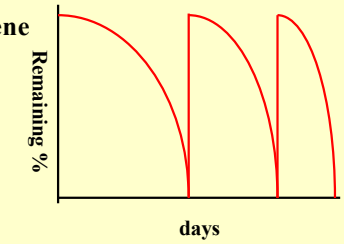
Organic matter → (Microbes) → CO_2, NH_4, HPO_3^{2-}, SO_4^{2-}

Secretion of soil enzymes

- Cellulase
- α-Glucosidase
- β-Glucosidase
- Protease
- Phosphatase
- Lipase

Decomposition and purification of harmful organic matter

- **Trichloloethylene**
- **PCB**
- **Dioxin**
- **Pesticides**



Direct decomposition and co-metabolism

Symbiotic relationship with plants (1)

- Nitrogen fixation

Symbiotic nitrogen fixation
Rhizobium, Cyanobacteria, Azolla
Associative nitrogen fixation
Bacterial nitrogen fixation
in the root zone of rice
Pseudomonas, Alcaligenes

Non-symbiotic nitrogen fixer bacteria

Proteobacteria group
Cyanobacteria group
Gram positive bacteria group
Green sulfur bacteria group
General Archaea group

Nitrogen fixation

$N_2 + 2H^+ + 8e^- + 16ATP \rightarrow 2NH_3 + H_2 + 16ADP + 16$ phosphate

Nitrogenase

$NH_4^+ \rightarrow$ Glutamine $\rightarrow$ Glutamic acid $\rightarrow$ $\rightarrow$
Protein, Nucleic acid

Ammonia assimilation enzymes

Root nodule bacteria (Rhizobium, Bradyrhizobium, Azorhizobium)

Grouped into Proteobacteria α

Symbiosis with legume plants and Ulmaceae plant, Parasponia

Legume plants are grown in 250×10^6 ha of land in the world, and 140 kg ha^{-1} of nitrogen are fixed.

(Total agricultural land area in the world is 1406×10^6 ha, in Japan 5.1×10^6 ha)

Soy bean root nodule

Cross section of root nodule.

Bacteroid tissue

Root nodules

Nitrogen fixation and the fertility of paddy field

- Cyanobacteria in the paddy water.
- Azolla
- Sesbania as green manure grown on the ridges of rice field
- Associative nitrogen fixing bacteria in the rhizosphere of rice

Sesbania

Cyanobacteria (blue green algae)

Have symbiotic relationships with

Lichens and mosses,

Azolla (Fern plant)

Cycad family (Gymnosperm)

Gunnera (Angiosperm)

Azolla

Actinomycetes (Frankia)

Belongs to Gram positive bacteria.

Forms root nodules with alder and Alnus firma as well as many other angiosperm trees in the temperate and tropic region.

Alder trees in the wetland

Symbiotic relationship with plants (2)

Mycorrhizal fungi

Symbiosis with 70 % of terrestrial plants.

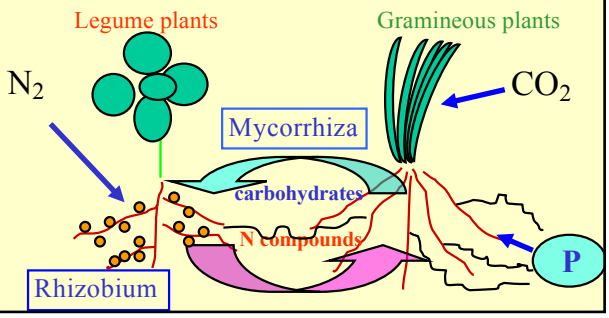
Fungi residing in the surface layer or inside of roots.

Help the absorption of phosphate and water.

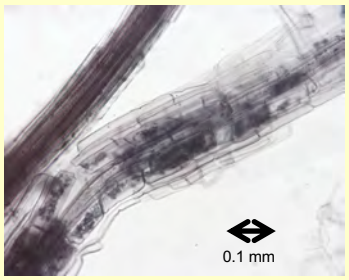
Arbuscular mycorrhizal fungi

Ectomycorrhiza

Transfer of nitrogen from N fixing plants to other plants



Mycorrhizal fungi in Timothy roots



Antagonism with disease causing germs

Abundant and heterogenous microbial flora prevents the spread of disease causing germs.

Bacillus subtilis controls the crop diseases.

Pseudomonas bacteria prevent the seedling diseases of tomato.

Non pathogenic *Fusarium* prevents various wilting and soft-rotting diseases of vegetables.

Microbial biomass in soil

Microbial biomass

occupies 0.3～5.0 % of total soil carbon.

In mineral soils 2～3% , in volcanic ash soils 0.3～1.0% in average.

Numbers of microbes: 10^7～10^9 / g soil
(10 millions ～1 billion /g)

(Fungi occupy ca. 70 % in upland field, grassland, forest, and orchard field, while bacteria occupy 80 – 98 % of total microbes in paddy soils.)

Total C and N, and biomass C contents in some Japanese soils.

Kind of soils	Texture	Total C (Mg/ha)	Total N (Mg/ha)	Biomass C (kg/ha)
Immature sand dune soil	S	9.4	0.86	32
Light colored ando soil	L	33.4	3.36	114
Humic ando soil	SiL	110	8.33	234
Brown forest soil	CL	20.6	1.69	276
Dark red soil	LiC	83.8	7.49	1,155

Sakamoto and Hodono: SSPN, 46, 483-490 (2000)
土壌サイエンス入門 (Introduction to soil science, 2005) p.169

Methods of soil biomass determination

1) Direct counting method

2) Culture method

3) Biochemical method

1. Direct counting

Jones-Mollison method

Count and measure the microbes in soil suspension with hemo-cytometer.

Fluorescent immuno-staining method

Staining the specific bacterium by its fluorescent antibody.

2. Culture method

Dilution Plate Method (DP)

Most Probable Number Method (MPN)

Substrate Induced Respiration Method (SIR)

3. Biochemical method

Chloroform fumigation method (applicable to all microbes)

→fumigation-culture and fumigation-extraction methods

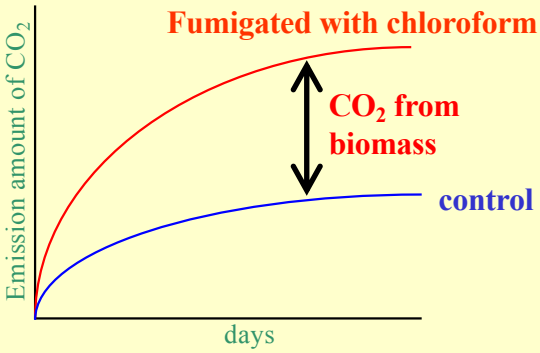
ATP method (applicable to all microbes)

Phospho-lipid (applicable to all microbes)

Muramic acid, diamino-pimelic acid (for bacteria)

Ergosterol (for fungi)

Microcalorimeter (applicable to all microbes)



Effect of chloroform fumigation on the CO2 emission from soil.

Functions of soil microbial biomass

1) Decomposer of organic matter
2) Source and stock of soil nutrients

Growth of crops and nutrients from microbial biomass

Relative % of nutrients contained in the microbial biomass of upland field. (Anderson and Domsch, 1980)

	C	N	P	K	Ca
Bacteria	25	4.5	1.5	0.8	0.4
Fungi	75	10.5	10.1	9.0	1.0
Total	100	15.0	11.6	9.8	1.4
Amounts of biomass nutrients in the field (kg/ha)					
		108	83	70	11

Showing the balance of nutrient uptake by crops and nutrients supplied from microbial biomass.

Nutrients in microbial biomass and absorbed amounts by crops

	Biomass nutrients	Absorbed nutrients
Germany, upland	100 kg N/ha	40 kg N/ha
England, upland	17 kg P/ha	6.8 kg P/ha
England, pasture	56.8 kg P/ha	22.7 kg P/ha
Philippines, paddy field	44 – 156 kg N / ha	40 – 100 kg N / ha